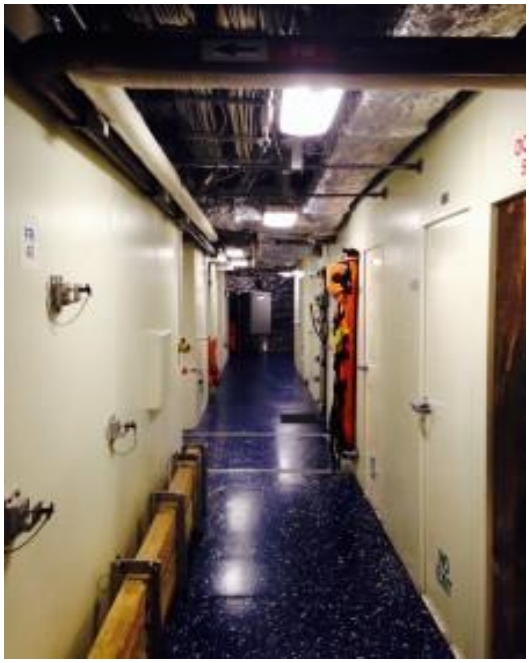
APPENDIX C-5

Watercraft LED Lighting

This appendix summarizes the movement toward LED lighting on watercraft, including the contribution LEDs will make to improve safety.

Introduction

The continuing improvement in light sources to Light Emitting Diode (LED) technology has made LED light sources affordable, reliable, durable, long life and cost efficient when associated with the maintenance of traditional light sources. LEDs are a Solid State Lighting (SSL) system from a semiconductor source of illumination rather than electrical filaments. There are many performance features which also make LEDs safer. Navy shipboard incident reports indicate that luminaire maintenance (e.g., changing bulbs) is a significant cause of electrical shocks. Under the right circumstances, these electrical shocks can result in an electrocution or after repeated shocks, long-term adverse health effects. SSL designs provide significant safety advantages compared to incandescent or fluorescent systems. Some of the many advantages over incandescent and fluorescent light systems include lower energy consumption, longer life, improved physical robustness, smaller size and faster switching. Modern LED lighting on military ships improves visibility, saves time and energy, reduces maintenance and safety risks.



Picture of naval ship retrofitted with LED lighting. Photo from: http://navylive.dodlive.mil/2014/10/02/seeing-the-light-shipboard-leds/

Discussion

The physical design of SSL systems provides a greater resistance to shock and vibration, significantly increasing the luminaires rated life. LED systems are smaller, lighter, use less energy, generate less heat and are more efficient than other lighting systems. This combination means that there are less maintenance opportunities for both bulb replacement and fixture maintenance, and less wear and tear on the entire distribution system. These characteristics all add up to a significant reduction in possible shocks hazards especially from a reduction in total system maintenance.

Military Specification MIL-DTL-16377J, dated 30 June 2014 covers fluorescent, incandescent and solid state lighting luminaires and associated parts for legacy replacement and new luminaire development fixtures (lights) and associated parts, used for detail and general illumination on naval ships and submarines. Unified Facilities Criteria (UFC) 3-530-01 revised in 2015 (Reference 7) provides detailed information for SSL, and more specifically, "requirements for the design of interior and exterior lighting systems and controls based on the Illuminating Engineering Society of North America's (IES) *Lighting Handbook Reference and Application, 10th Edition.*"

LEDs have many advantages:

1. **Efficient -** LEDs are capable of 135 lumens (a measure of light output) per watt (a measure of energy consumption).
2. **Long Lifetime** - 50,000 hours or more.
3. **Rugged** - LEDs are called "Solid State Lighting" (SSL) because they are made of solid material with no filament or tube or bulb to break.
4. **No warm-up period** - LED's light instantly, in nanoseconds.
5. **Not affected by cold temperatures** - LEDs will startup even in subzero weather.
6. **Directional** - LEDs direct the light where it is needed.
7. **Controllable** - LED's can be controlled for brightness and color.
8. **Environmental Disposal Considerations** – LEDs contain no hazardous mercury.
9. **Safe** – LEDs don't present a hazardous chemical problem if broken and last longer than fluorescents and incandescents, thus reducing the potential for injuries from shocks or falls when replacing expired bulbs.

LED Lighting, A Business Case Analysis

LED lighting provides a much longer useful lifespan, better efficacy (energy efficiency) and LED are inherently rugged and shock-resistant; a major benefit for most military lighting applications. LED lighting implementation can contribute to the reduction of fossil fuel requirements. The primary disadvantage is cost, with higher upfront investment compared to other lighting options. Heat generation is another area where LED offer benefits. Incandescent bulbs produce light by passing an electrical current through a metal filament until it glows. They emit 90% of their energy as heat. In fluorescent bulbs, an electrical current is passed through gases, generating ultraviolet light which is converted to visible light by the phosphor coating on the inside of the tube. Approximately 80% of the energy emitted from a fluorescent tube is in the form of heat. LED produce light much more efficiently. Additionally, LEDs generate light in a specific direction, while fluorescent and incandescent bulbs emit light and heat in all directions. LED are clearly better because of lower life cycle costs and energy savings, as well as providing all-around better lighting levels. Also, Fleet service life extensions, beyond thirty

years are becoming increasingly common. Today's newest watercraft will see more than forty years of service, increasing the payback opportunity for cost saving innovations such as LED lighting.

An LED is a semiconductor device which converts electricity into light. Each diode is about 1/4 inch in diameter and uses about ten milliamps to operate at about a tenth of a watt. LED are small in size, but can be grouped together for higher intensity applications. LED fixtures require a driver which is analogous to the ballast in fluorescent fixtures. The efficacy (efficiency of the bulb to convert electricity into light) of a typical LED is approximately 20 lumens per watt (LPW), though efficacies of up to 100 LPW have been created in the laboratory. For comparison, incandescent bulbs have an efficacy of about 15 LPW and compact fluorescents are about 60 LPW, depending on the wattage and lamp type.

LED Safety Discussion

LEDs have three main safety advantages:

(1) They are not regulated as hazardous materials or hazardous waste,
(2) There is less maintenance and chance for electric shock/electrocution, and
(3) They use a lower voltage/power, reducing the risk for mishaps.

Let's look at each of these advantages in more detail.

(1) LEDs are not regulated as hazardous materials or hazardous waste:

Watercraft must dedicate storage space for fluorescent tubes which must be handled and stored as hazardous waste until proper licensed hazardous waste disposal facilities are utilized. LED are not considered hazardous waste and can be handled and stored as regular waste. There is no need for special storage and handling procedures for LED as hazardous waste.

(2) There is less maintenance and chance for mishaps:

Current incandescent and fluorescent fixtures are considered maintenance intensive and are a high maintenance item for watercraft. A typical fluorescent fixture has three points of failure—the bulb, ballast, and starter. These components increase the maintenance requirements for fluorescent fixtures. There is a high prevalence of shocks when changing light bulbs on watercraft. Environmental conditions are more hazardous because of humid environment and general weather and working conditions. With a decrease in the need to change out bulbs, there will be less of a risk for shock or electrocution. A key safety benefit of the LED long lifespan is that maintenance is not required over the next 10 years, compared to fluorescent lamps which need to be replaced approximately every two years and incandescent which need to be replaced

even more often. Watercraft maintenance requirements are reduced and space savings are achieved with a corresponding decrease in spare parts.

(3) LEDs use a lower voltage/power, reducing the risk for mishaps:

LEDs also offer increased illumination levels which would improve general safety and possibly reduce slip, trip and fall hazards and improved quality of lighting throughout a watercraft's life cycle at lower power consumption. Because of this lower power consumption, there is less wear and tear on the generation and distribution systems onboard. This lower wear and tear relates directly to fewer maintenance evolutions, thus resulting in less chances of electrical mishaps or shocks and less chance of system degradation leading to system failures.

Summary of LED Advantages:

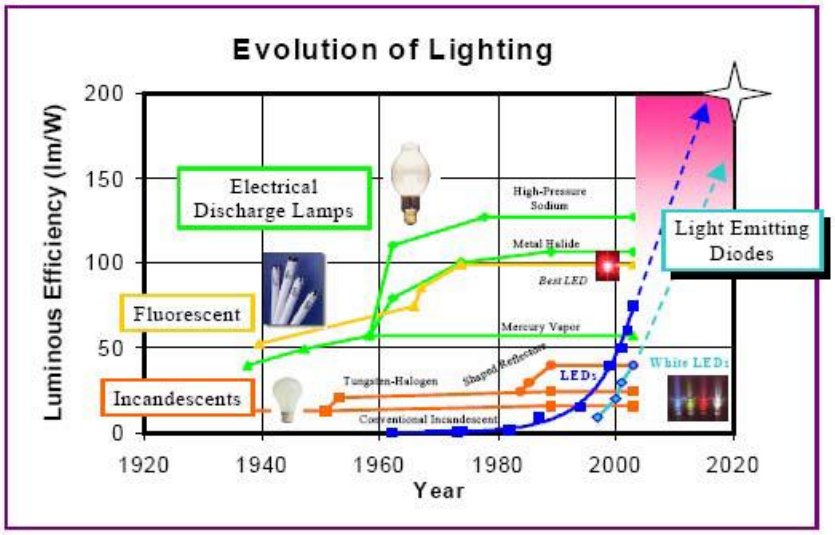
- Current lifetimes of LED-based luminaires are predicted to be 50,000 hours compared to 9,000 hours for typical fluorescent luminaires and 1,000 hours for incandescent
- LED-based lighting systems will also save energy: 70+% for incandescent replacement, 40+% for white fluorescent replacement
- Potential to reduce size and weight of numerous fixture designs with correctly designed LED-based luminaires
- No hazardous waste.
- Less maintenance and exposures to shock hazards.
- More light per watt than incandescent bulbs (useful in battery powered or energy saving devices).
- Can emit light of an intended color without the use of color filters that traditional lighting methods require. This is more efficient and can lower initial costs.
- Can be designed to focus its light. Incandescent and fluorescent sources often require an external reflector to collect light and direct it in a usable manner.
- When used in applications where dimming is required, LEDs do not change their color tint as the current passing through them is lowered, unlike incandescent lamps, which turn yellow.
- Ideal for use in applications that are subject to frequent on-off cycling, unlike fluorescent lamps that burn out more quickly when cycled frequently, or HID lamps that require a long time before restarting.
- Difficult to damage with external shock. Fluorescent and incandescent bulbs are easily broken if subjected to external shock.

COMPARISON OF LIGHTING

	Incandescent	Fluorescent	LED	Interpretation
Efficacy (See Note 1) (lumens/watt)	12-15	50-100	60	More efficient bulbs provide more light using less energy.
Lifespan (hours)	1,000	10,000–20,000	50,000	More hours results in less maintenance and possible exposure to electric current
Cost (residential lighting	$15	$35	$80	Up front costs only. Life cycle costs are not quantified.

Note 1: Efficacy is the efficiency of the bulb to convert electricity into light.
Source: Reference 2.

The following figure shows graphically the increasing performance of LED lights, as compared to traditional sources. LED performance has been increasing ten-fold per decade since the mid 1960s, and currently meets or exceeds that of most other existing lighting products.



Source: Reference 2.

Examples of Watercraft that are using LEDs:

- In Oct 2014, Rear Admiral Slates, Director, Chief of Naval Operations for Energy and Environmental Readiness, wrote an article on Shipboard LEDs, noting that the USS Chafee (DDG 90), USS Preble (DDG 88), and USS Independence (LCS2) were retrofitted with LEDs. (reference 10).

- In April, 2015, Secretary of the Navy Ray Mabus "directed that brighter, longer-lasting and more energy-efficient lighting be installed in U.S. Navy ships under construction as part of a strategy designed to help increase these ships' time on-station, decrease time spent on maintenance, and prevent shipboard injuries.[1]" (reference 11).
- The first ship with complete LED installation will be DDG 117, USS Paul Ignatius, scheduled for completion and commissioning in 2018. This Arleigh Burke class guided-missile destroyer currently being built with four basic LED designs: 1) 2-foot LED lamps; 2) globes in large and small sizes to install in high-traffic areas such as cargo holds and cargo elevators; 3) explosion-proof globes as needed; and 4) bunk lights, complete with their own fixture.

Picture of the USS Jason Dunham, DDG109, a current Arleigh Burke class guided-missile destroyer commissioned in 2009 and prior to movement to LEDs. Photo from: http://en.wikipedia.org/wiki/USS_Paul_Ignatius

Conclusion

- LED illumination is clearly better than the alternatives.

References for further information

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